

Roundtail Chub Population Assessment in the Lower Salt and Verde Rivers, Arizona

State Wildlife Grant Final Report



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Roundtail Chub Population Assessment in the Lower Salt and Verde Rivers, Arizona

Scott D. Bryan and Matthew W. Hyatt

Abstract. - Roundtail chub were collected during spring and fall 2003 in the lower Salt and Verde rivers to determine population size, size structure, condition, and habitat use. We collected and PIT tagged 262 roundtail chub using a combination of experimental gill nets and canoe electrofishing. The majority of roundtail chub were collected in the upper 16 km of the study area, primarily in lateral scour pools and runs. Movement data from recaptured fish showed that chub were relatively sedentary. Although two fish moved nearly 3 km, mean distance traveled by all recaptured fish was only 0.5 km. Length-frequency distributions indicate that the population is comprised almost entirely of large adults with minimal recruitment. Mean relative weight values ranged from 95 to 125, suggesting that chub in the study area are in very good condition. The estimated population size of roundtail chub in the lower Salt and Verde rivers during 2003 is 1,657 (95% CI = 1,097-2,742), which represents a 74% decrease from just three years ago. Based on these results, we conclude that the roundtail chub population in the lower Salt and Verde rivers is declining rapidly due to low recruitment and high natural mortality. We recommend immediate management actions be taken to ensure the persistence of this population of roundtail chub.

Roundtail chub (*Gila robusta*) are a unique native fish in Arizona because they are managed as both a sportfish and a Species of Special Concern (AZGFD 1996). Although not federally listed as threatened or endangered, roundtail chub distribution and abundance is decreasing throughout its range (Voeltz 2002). Reasons for the decline include alteration of the historic hydrograph (dam construction), habitat degradation, and predation by and competition with nonnative fishes (Minckley and Deacon 1991).

Prior to 1998, Arizona Game and Fish Department (AZGFD) had few records of roundtail chub inhabiting the lower Verde River below Bartlett Dam (Girmendonk and Young 1997). Similarly, very few roundtail chub had been reported in the lower Salt River below Stewart Mountain Dam (Clarkson 1998). This led biologists to believe that the roundtail chub population in the lower Salt and Verde rivers was somewhat sparse. However, a multi-year research project conducted from 1999-2000

indicated that roundtail chub were more abundant than previously thought (Bryan and Robinson 2000).

Bryan and Robinson (2000) provided important baseline information for population size, size structure, habitat use, movement, and growth of roundtail chub in the lower Salt and Verde rivers. They suggested that continued monitoring was needed to determine population stability and to identify factors that affect reproduction and recruitment. This report summarizes the continued monitoring efforts in 2003, which was aimed at evaluating the current status of the population. We also consider the effects of prolonged drought on roundtail chub in the lower Salt and Verde rivers.

The primary objectives of this study were to determine the current population size, size structure, and condition of roundtail chub within the study area. We also make comparisons with results reported by Bryan and Robinson (2000; hereafter referred to as the 2000 study) to evaluate trends in the population status. In

addition, the low recapture rates experienced during 1999-2000 may be explained by poor retention of Passive Integrated Transponder (PIT) tags. Therefore, a secondary objective was to determine retention rates of PIT tags by roundtail chub.

Methods

Study Area

The study was conducted in the lower Salt River, between Stewart Mountain Dam and Granite Reef Dam, and the lower Verde River, between Bartlett Dam and its confluence with the Salt River (Figure 1). Both stretches of river are regulated by Salt River Project (SRP) and provide hydroelectric power and water to the Phoenix metropolitan area.

The lower Salt River flows through Sonoran desert scrub and low gradient, tamarisk-mesquite flats for approximately 21.5 km before reaching Granite Reef Diversion Dam, where it is diverted into canals for the city of Phoenix. During winter, water is stored in the four reservoirs above Stewart Mountain Dam and flows below the dam are held at the required minimum of 8 cubic feet per second (cfs). In this time of low flow, fish are restricted (and sometimes stranded) to shallow runs and several large pools (typically < 3 m deep). During summer, water and electric demands in the Phoenix area increase, and as a result, flows in the lower Salt River increase to 800-1200 cfs. The high flows create a number of lateral scour pools, high gradient riffles (rapids), and swift runs.

The lower Verde River flows approximately 41 km from Bartlett Dam to the Salt River confluence. The upper portion of the river has a high gradient and is bound by canyon walls. It then slowly opens into desert scrub brush flatlands as it flows through the Tonto National Forest, Fort McDowell Yavapai Nation, and Salt River Pima-Maricopa Indian Community. During winter, flows typically range from 400 -

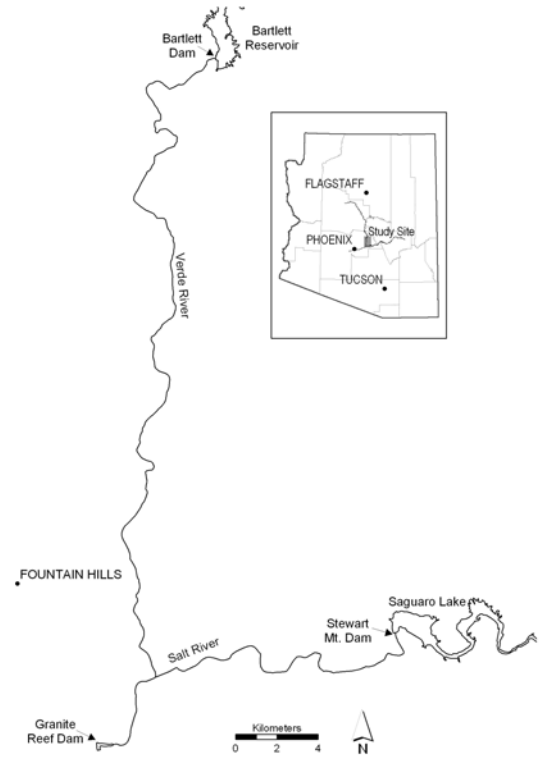


FIGURE 1. - Map of the lower Salt and Verde rivers.

1,000 cfs, which provided highly variable habitat consisting of moderate to deep pools, long runs, and both high and low gradient riffles. Summer flows are held relatively constant, between 125 and 250 cfs, and the river becomes very shallow, but still includes diverse habitat for fish.

Population Characteristics

We sampled the lower Verde River twice in spring and twice in fall, 2003. The lower Salt River was sampled three times during 2003, twice in spring and once in fall (equipment failure precluded a second sample during fall). Sites where roundtail chub were collected during the 2000 study were sampled during each trip (fixed sites). In spring 2003, we also sampled an equal number of random sites in each river (44 in the Verde River, 7 in the Salt

River). However, since no chub were collected at random sites during spring sampling, we assumed that fixed sites were representative of the population and sampled only fixed sites in fall.

Fish were collected using a combination of gill netting and canoe electrofishing. Up to three experimental gill nets (2.4 m x 45.5 m, with mesh sizes of 12.7, 25.4, 38.1, 50.8, 63.5, and 76.2 mm) were set perpendicular to flow and the canoe electroshocker (600 volts; 6-8 amps) was fished over the nets. Nets were not fished longer than 30 minutes to avoid mortality. When flows were too high or water was too shallow to effectively fish gill nets, only the canoe electroshocker was used.

Upon capture, roundtail chub were measured (TL, ± 1 mm), weighed (± 1 g), and scanned for the presence of an internal PIT tag. Unmarked individuals ≥ 90 mm were injected with a PIT tag, and tag numbers of recaptured fishes were recorded. Tags were injected posterior to the pelvic girdle into the abdominal body cavity. Habitat type where each fish was collected was recorded (McCain et al. 1990) and the location was mapped using GPS.

A length-frequency histogram was generated to evaluate the size structure of the population and identify possible gaps in year classes. Relative weight (W_r) was used to describe body condition (Wege and Anderson 1978):

$$W_r = \frac{\text{Weight}(g)}{W_s} \times 100$$

where standard weight (W_s) was calculated using the equation developed by Didenko et al. (2004):

$$\log_{10}(W_s) = (-5.065 + 3.015) \times \log_{10}(\text{length})$$

Movement of roundtail chub was assessed using data from recaptured fish. The distance each fish moved was calculated based on consecutive capture locations. Finally, a distribution-frequency figure was created to

illustrate differences in longitudinal abundance of roundtail chub within the study area.

Length and weight data were compared between rivers and years (2000 vs. 2003) using t-tests. Proportional data (e.g. habitat use, distribution frequency) was compared between rivers and years using chi-square analysis. Data was considered to be significantly different when $P < 0.05$.

Population Estimate

The joint hypergeometric maximum likelihood estimator (JHE; Bartmann et al. 1987, White and Garrott 1990, Neal et al. 1993) was used to calculate a population estimate from mark/recapture data of PIT tagged fish. The JHE is an adaptation of the Lincoln-Petersen estimate for closed populations. We considered fish in both the Salt and Verde rivers to be from a single population for estimates of population size because fish can move freely between the two rivers (Bryan and Robinson 2000). Furthermore, we treated the population of roundtail chub as a closed population both geographically and demographically because there was no (or rare) opportunity for immigration or emigration and during our study we assumed negligible recruitment into the tagged population. We also assumed equal mortality for tagged and untagged fish (Seber 1973).

Only fish tagged in 2003 were used for population estimates; i.e. chub captured in 2003 that were tagged during the 2000 study were considered initial captures for the 2003 estimate (to meet assumptions of the closed population). The population estimate was calculated using NOREMARK software (G.C. White, Colorado State University, 1996). Confidence intervals were determined with the profile likelihood method (Venzon and Moolgavkar 1988).

Pit Tag Retention

In February 2004, roundtail chub were

collected from a large pool on the lower Verde River to determine short-term PIT tag retention. This site was selected because it was easily accessible and previous sampling indicated that it contained a relatively large number of roundtail chub in a small area (Bryan and Robinson 2000). Fish were collected using a combination of electroshocking and gill nets, as described above. We also attempted to use large hoop nets, but were unsuccessful in capturing fish.

Upon capture, roundtail chub were processed as above. Tag numbers of recaptured fishes were recorded and a second mark, in the form of a white floy tag, was attached near the dorsal fin. Unmarked individuals were injected with a PIT tag and a white floy tag. Over a period of 90 days, this site was resampled every 30 days utilizing the same protocol. A PIT tag was considered lost if a recaptured fish possessed a floy tag but not a PIT tag.

Results

Population Characteristics

During 2003, roundtail chub were collected at 34 sites on the lower Verde River and 2 sites on the lower Salt River (Figure 2). In the lower Verde River, 272 roundtail chub were captured; 242 were PIT tagged, 16 were recaptures, 13 were sacrificed for aging otoliths, and 6 escaped prior to tagging. In the lower Salt River, 25 chub were captured, of which 20 were PIT tagged and 5 were recaptures.

Roundtail chub were more numerous and more evenly distributed in the upper 16 km of the Verde River, below Bartlett Dam, than in the lower 25 km (Figure 3). There was an increase in the proportion of chub collected in the upper 16 km of the river from 64 % in 2000 to 88 % in 2003 (chi-square, $P = 0.000$). In the Salt River during 2003, roundtail chub were sparsely distributed with fish being captured at only 2 sites located 9.7 and 10.7 km downstream of Stewart Mountain Dam. During 2000, chub

were collected at 6 sites in the Salt River ranging from 5 –21 km from the dam.

The length-frequency histograms of roundtail chub collected during spring and fall 2003 in the lower Salt and Verde Rivers (Figure 4) indicate that this population is comprised almost entirely of large fish (> 35 cm), with few small fish (< 35 cm), and an apparent absence of juveniles (< 25 cm). Seasonal growth could not be detected in these length-frequency histograms, as spring and fall length distributions were very similar. Length-frequency histograms from the 2000 study are provided in Appendices A and B.

Adult roundtail chub (> 25 cm) in the lower Salt River had a higher mean weight (t-test, $df = 290$, $P = 0.000$) and a mean total length greater (t-test, $df = 229$, $P = 0.000$) than those collected in the lower Verde River (Table 1).

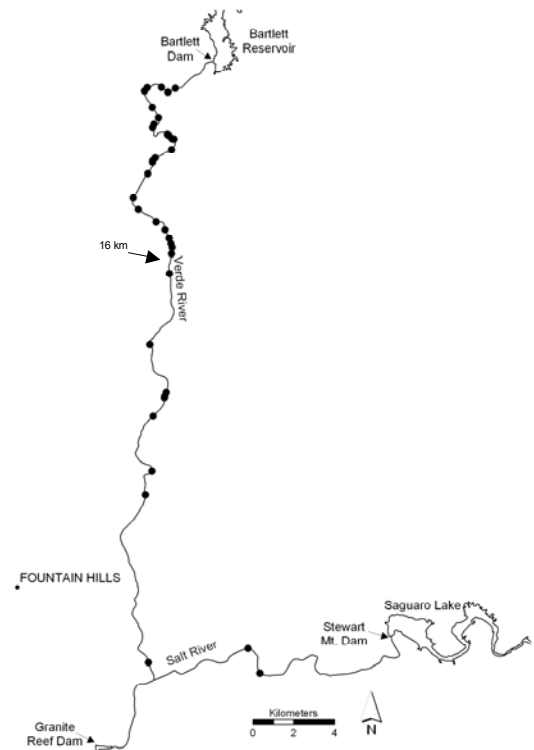


FIGURE 2.- Locations of roundtail chub captured and PIT tagged in the lower Salt and Verde rivers, 2003.

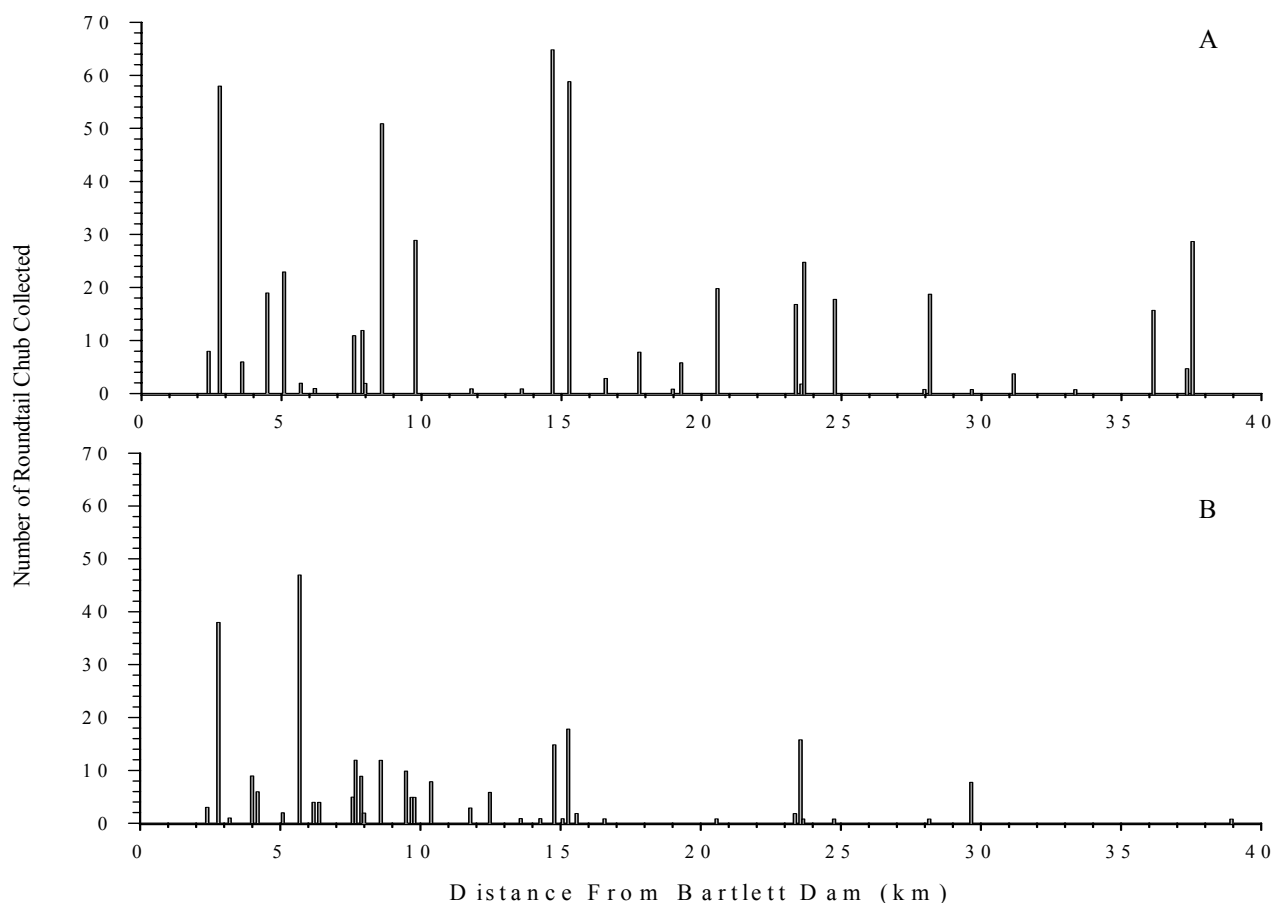


FIGURE 3. - Distribution and abundance of roundtail chub collected in the lower Verde River, Arizona during 1999-2000 (A; Bryan and Robinson 2000) and in 2003 (B).

TABLE 1. - Length and weight statistics from roundtail chub collected in the lower Salt and Verde rivers, 2000 and 2003. Standard errors of means are in parentheses.

	Salt River		Verde River	
	2000	2003	2000	2003
Length	n=50	n=25	n=879	n=267
Mean	363 (13)	474 (5)	367 (2)	417 (3)
Min	72	430	81	254
Max	502	523	492	552
Weight	n=50	n=20	n=582	n=211
Mean	568 (48)	1283 (63)	449 (8)	680 (16)
Min	3	930	4	158
Max	1406	1830	1206	1865

Within the lower Verde River, chub collected in the upper 16 km were significantly smaller (mean TL = 414 mm) than chub collected in the lower reaches of the river (mean TL = 440 mm; t-test, $df = 254$, $P = 0.001$).

Roundtail chub collected in 2003 had a mean total length greater than those collected in the 2000 study for both the lower Salt River (Table 1; t-test, $df = 73$, $P = 0.000$) and the lower Verde River (t-test, $df = 1,144$, $P = 0.000$). The largest roundtail chub collected in 2003 was caught in the lower Verde River and measured 552 mm and weighed 1,826 g.

Mean W_r for roundtail chub (Table 2) in the lower Salt River was significantly higher than W_r in the lower Verde River during 2003 (t-test, $df = 229$, $P = 0.000$). In 2003, mean W_r of

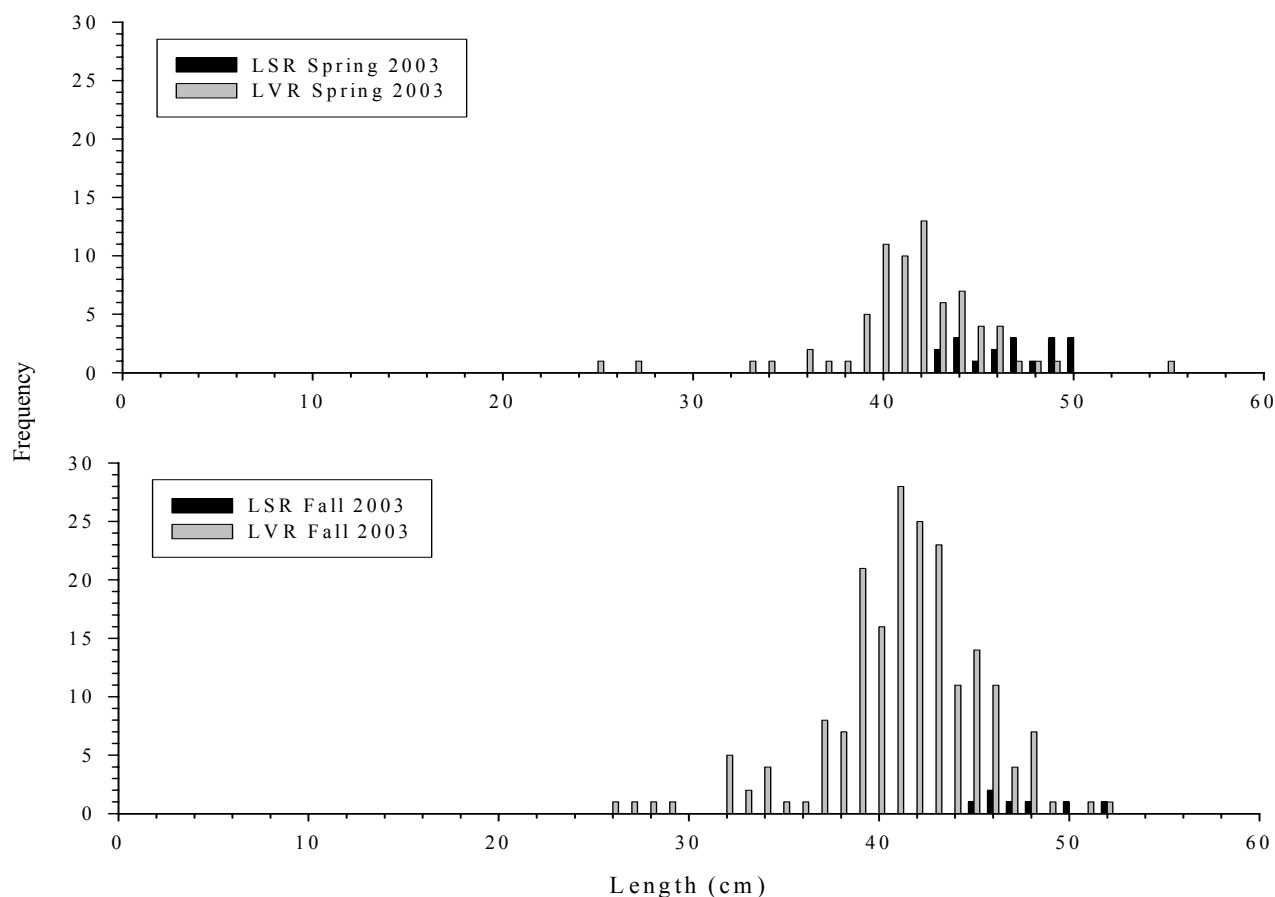


FIGURE 4. - Length-frequency histograms of roundtail chub collected during the spring and fall, 2003 in the lower Salt River (LSR) and lower Verde River (LVR), Arizona.

roundtail chub (Table 2) was higher than that calculated for fish caught in 2000 in both the Salt (t-test, $df = 68$, $P = 0.000$) and Verde rivers (t-test, $df = 791$, $P = 0.000$).

Roundtail chub in the lower Salt River were collected primarily in lateral scour pools in 2003 (Table 3); whereas in the 2000 study they were found primarily in mid-channel pools (chi-square, $df = 2$, $P = 0.000$). In 2003, the majority of roundtail in the lower Verde River were collected in lateral scour pools and runs, with a small percentage collected in low gradient riffles, compared to the 2000 study when fish were more evenly distributed among different habitat types (chi-square, $df = 6$, $P = 0.000$).

TABLE 2. - Mean relative weight (W_r) of roundtail chub collected in the lower Salt and Verde rivers in 2000 and 2003. Standard error is in parentheses.

	Salt River	Verde River
2000	106 (1.8)	90 (0.7)
2003	125 (4.4)	95 (0.7)

The majority of recaptured roundtail chub exhibited site fidelity (remaining in the same area for an extended period; Ball 1943); 11 fish (68.8%) did not move, 3 fish (18.8%) moved upstream, and 2 fish (12.5%) moved downstream. Overall mean distance traveled

TABLE 3. - Habitat characteristics of roundtail chub collected in the lower Salt and Verde rivers, 2000 and 2003. Values represent the percentage of fish collected in each habitat type.

Habitat	Salt River		Verde River	
	2000 n = 50	2003 n = 25	2000 n = 879	2003 n = 261
Pool				
Backwater Pool				1.5
Eddie Pool			0.2	2.3
Lateral Scour Pool	10.0	92.0	23.0	42.1
Mid-Channel Pool	82.0	8.0	11.6	7.7
Riffle				
High Gradient			4.9	6.9
Low Gradient			20.3	8.0
Run	8.0		40.0	31.4

was 0.5 km (SE = 0.3) and the furthest movement by a single fish was 2.8 km. Movement was only detected for fish initially captured in early September and then recaptured two weeks later. During the weeks prior to these movements, flows decreased considerably and remained low and relatively steady throughout the sampling period (Figure 5).

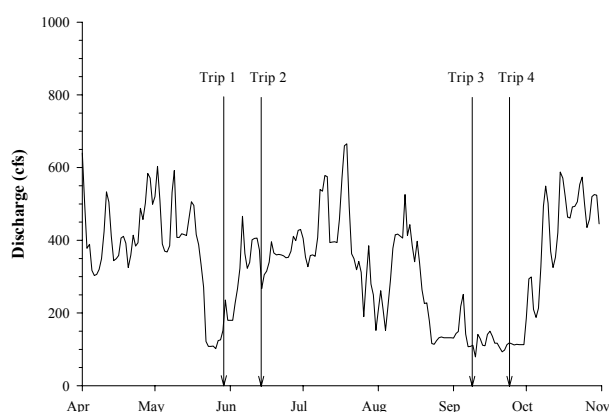


FIGURE 5. – Mean daily discharge in the lower Verde River during 2003. Lines represent sampling trips; Trip 1 was May 27, Trip 2 was June 10, Trip 3 was September 8 and Trip 4 was September 22.

Population Estimate

In 2003, 262 roundtail chub from the lower Salt and Verde rivers were marked; 16 of which were recaptured on subsequent trips (and two were recaptured on multiple occasions). The number of individuals marked in 2003 was 70% less than the number of fish marked in the 2000 study (Table 4), although effort differed slightly. The modified Lincoln-Petersen population estimate for roundtail chub in the lower Salt and Verde rivers for 2003 was 1,657 individuals with a 95% confidence interval of 1,097 – 2,742; which is a 74% decrease from the 2000 estimate of 6,424 individuals, with a 95% confidence interval of 5,048-8,397 (Table 4).

PIT Tag Retention

We tagged 29 fish with a combination of PIT and floy tags in February and March 2004. Only 2 double-tagged fish were recaptured during the 90-day evaluation period (one in March and one in May). Both recaptures retained their PIT tag, but one floy tag was lost. Although retention of PIT tags was 100%, the

TABLE 4. - Number of roundtail chub marked and recaptured during each sampling trip in 2000 and 2003 in the lower Salt and Verde rivers, with modified Lincoln-Peterson population estimates and 95% confidence intervals for each year.

Trip	# Marked	# Recaptured
2000 (51 sites/trip)		
1	178	--
2	162	3
3	40	0
4	208	18
5	155	12
6	135	20
2000 Population Estimate (95% CI)		
6,424 (5,048 - 8,397)		
2003		
1 (102 sites)	70	--
2 (102 sites)	16	4
3 (51 sites)	92	4
4 (44 sites)	84	8
2003 Population Estimate (95% CI)		
1,657 (1,097 - 2,742)		

low sample size does not allow an accurate calculation of PIT tag retention rates.

Discussion

Population Characteristics

The lower Salt and Verde rivers were sampled at fixed and random sites throughout their entire lengths, but the majority of roundtail chub were collected in the upper 16 km of the lower Verde River. This section of the river is confined within steep canyon walls resulting in a high stream gradient, characterized by numerous pool-run complexes adjacent to swift moving riffles, which is the preferred habitat of adult roundtail chub (Bestgen and Propst 1989; Karp and Tyus 1990; Rinne and Minckley 1991). There are also several shoreline eddies available in the upper 16 km, which is the preferred spawning habitat for roundtail chub

(Vanicek and Kramer 1969, Karp and Tyus 1990). Abundance of roundtail chub decreased abruptly approximately 16 km downstream of Bartlett Dam as the river becomes wider and shallower with a more moderate gradient, with few areas of preferred habitat. In addition to more suitable habitat, roundtail chub may prefer the upper 16 km because the water is cooler and there are fewer predators and non-native species than in the lower reaches (Bryan and Robinson 2000).

Bryan and Robinson (2000) also found a high abundance of chub in the upper 16 km (64%), but it represented a significantly lower proportion of the total catch than was found in 2003. The increase in the proportion of roundtail chub in the upper 16 km from 2000 to 2003 may be due to several factors, including an increase in the abundance of nonnative fishes in the lower reaches of the river (personal observation) which could have resulted in predation on smaller individuals. In addition, chub in the lower reaches were significantly larger, and therefore probably older, and may be experiencing a higher rate of natural mortality than fish in the upper 16 km.

Collection of roundtail chub from the lower Salt River proved to be somewhat difficult. Although low flows during winter (< 10 cfs) generally force the fish to congregate in deep pools (which effectively limits their movement), sampling techniques may have been ineffective. Bryan and Robinson (2000) snorkeled sites in the lower Salt River just after electrofishing and approximated that they were collecting only 10% of the roundtail present at each site. It was thought that using a combination of gear types (electrofishing over gill nets) would increase the likelihood of capture. However, the electrofisher was likely ineffective due to the high conductivity water (~ 1255 μ S/cm). Sampling during late spring and summer was not possible due to extremely high flows (typically > 1,000 cfs). Other methods, such as trammel nets, hoop nets, seining, and backpack electrofishing were even less effective for

collecting adult roundtail chub in the lower Salt River (Bryan et al. 2000).

Despite difficulties in sampling, the low number of roundtail chub collected from the lower Salt River is probably a reflection of their low abundance due to a lack of suitable habitat (dominated by long runs and riffles), and a high abundance of nonnative fishes (Bryan et al. 2000). The same difficulties do not exist when sampling the lower Verde River; water conductivity is approximately 520 $\mu\text{S}/\text{cm}$, which allows for more effective electrofishing (Reynolds 1996).

Length-frequency distributions, can provide insight into the dynamics of populations and aid in identifying problems such as year-class failures or low recruitment, slow growth, or excessive annual mortality (Anderson and Neumann 1996). The length-frequency distributions developed from roundtail chub collected in 2003 indicate that the population is comprised almost entirely of large adults with little or no recruitment. Although length-frequency histograms from 1999 and 2000 (Appendix A and B, respectively; Bryan and Robinson 2000) also show a large adult population, there is evidence of reproduction and recruitment. Chub that apparently hatched in 1998 were collected in spring 1999 as 90 - 120-mm 1-year olds, and their growth into the adult population can be seen in samples during summer 1999 and into 2000. The absence of juvenile and small adult chub in 2003 suggests that the last significant spawn may have occurred in 1998.

The appearance of juveniles in the 1999 sample followed a spring flood event in 1998, which lends credibility to the hypothesis that, for many native desert fish species, including roundtail chub, successful spawning and subsequent recruitment is related to the occurrence of significant flood events (Nesler et al. 1988, Poff and Allan 1995, Brouder 2001). However, it should be noted that roundtail chub have sustained a viable population in the lower Salt and Verde rivers despite long periods (up to

twenty years) without a significant flood event (see Appendix C). This suggests that flood events are not solely responsible for successful spawning and recruitment; at least not at the level required to sustain a population.

Roundtail chub collected in the lower Salt and Verde rivers achieved greater lengths than reported in most studies (Vanicek and Kramer 1969, Neve 1976, Bestgen 1985, Ziebell and Roy 1989, Brouder *in prep*). Bryan and Robinson (2000) suggested that this might be due to factors such as water temperature, food availability, or habitat. These fish may also be longer-lived than fishes found in smaller streams. Brouder (*in prep*) reported a maximum age of seven for roundtail chub in the upper Verde River, which is similar to those found in the Gila River Basin, New Mexico (Bestgen 1985), and the Green River, Utah (Vanicek and Kramer 1969). Preliminary ages of otoliths collected from chub in the lower Verde River suggests that these fish may live up to 11 years (AZGFD, unpublished data).

Liao et al. (1995) suggested that low values of W_r reflect competition for limited prey resources. However, they also indicated that W_r is only a good predictor of prey availability when diets are relatively narrow. Roundtail chub are omnivorous (Girmendonk and Young 1997), so the high values of W_r observed in the lower Salt and Verde rivers during 2003 are not likely reflective of a surplus of food, rather simply indicate that prey is not a limiting factor. Anderson and Neumann (1996) suggest that fish may not be making the best use of prey when W_r values are well above 100. Roundtail chub in the lower Salt River had W_r values of 125, and may indicate that fish are converting food resources to somatic growth rather than reproductive development. It could also suggest that fish have reached near maximum length, and growth is achieved by an increase in body weight rather than body length (as observed in some humpback chub populations; Bill Persons, AZGFD, personal communication). Regardless, chub in both the lower Salt and Verde rivers are

in very good condition, and natural mortality is probably not a function of poor physical health (Newsome and Leduc 1975), but is more likely a result of old age.

Similar to the findings of Bryan and Robinson (2000), PIT tag data indicated roundtail chub move very little in the lower Salt and Verde rivers (high site fidelity). Siebert (1980) and Brouder et al. (2000) also found that roundtail chub move very little in small Arizona streams. We expected movement, if detected, to be associated with a spike in flow or a spawning migration. Bryan and Robinson (2000) observed only one large movement (7.5 km) by a roundtail chub in the lower Verde River, which occurred just after a spike in discharge. Kaeding et al. (1990) found that roundtail chub moved extensively (up to 34 km) in a large river, which was related to a spawning event when discharge was near its seasonal high (or was receding). The few fish for which we were able to detect movement, did so at a time when discharge was near its seasonal low. According to Bryan and Robinson (2000), the lack of significant movement by roundtail chub in the lower Salt and Verde rivers may be attributed to an abundant supply of food, habitat, or an absence of a spawning migration due to minimal spring spike flows from the dams (exacerbated by drought conditions).

Population Estimate

Although initial research (Bryan and Robinson 2000) indicated that the roundtail chub population in the lower Salt and Verde rivers was relatively large, we found that the size of this population has decreased by 74% in just three years. Despite this reduction in population size, the majority of the individuals we collected were in very good to excellent physical condition. Therefore, we do not believe the decline is a result of food availability. Although a variety of factors probably have caused this decline (including an increasing number of nonnative competitors and

predators), we believe that the primary cause is diminished recruitment due to a lack of significant spikes in flow in the last five years (Poff and Allan 1995, Rinne and Stefferud 1996, Brouder 2001). The last flood event occurred in 1998, which coincides with the last significant roundtail chub spawning event in the lower Salt and Verde rivers. That means that the population consists primarily of individuals at least 5 years old. Assuming a maximum life expectancy of 7-11 years for roundtail chub (Brouder et al. 2000; Vanicek and Kramer 1969), a large portion of the population in the lower Salt and Verde rivers may be lost to natural mortality over the next five years.

PIT Tag Retention

Mark-recapture data are often used to investigate growth or migratory behavior as well as population level parameters, such as population size and survival rates (Buzby and Deegan 1999). Tag loss complicates the use of mark-recapture data for population estimates by reducing sample size, as well as introducing bias into estimates of population size and survival rates (Ricker 1975; Arnason and Mills 1981). Since tag loss varies with fish species, Buzby and Deegan (1999) recommend tag retention rates be developed for each species separately. Unfortunately, due to insufficient recapture data, we were unable to calculate PIT tag retention rates for roundtail chub. However, Childs (2002) conducted a PIT tag retention study with bonytail chub and found tag loss to be negligible (96.6% retention over a three month period). Therefore, we believe roundtail chub tag retention is similar to that of bonytail and therefore inconsequential, having little or no affect on our population estimates.

Conclusions and Recommendations

The distribution and abundance of roundtail chub is declining throughout its historic range. In Arizona, statewide declines have been

attributed to aquifer pumping; stream diversion; alteration of the historic hydrograph; and predation by and competition with nonnative fishes (AZGFD 1996). As roundtail chub numbers continue to dwindle, each remaining population becomes increasingly important to the survival of the species. The decline of the roundtail chub in the lower Salt and Verde rivers raises serious concern that extirpation of this population may be closer to becoming a reality; especially considering the short time span over which this decline has occurred.

Immediate management action needs to be taken to ensure the maintenance of this (and all) roundtail chub population. To reduce the negative impacts of competition and predation, the introduction of nonnative fishes into roundtail chub habitat should be carefully evaluated and probably suspended, especially with regards to predatory species. In the lower Salt and Verde rivers, rainbow trout (*Oncorhynchus mykiss*) stocking is an important management tool, but should be thoroughly evaluated to determine its economic impact and the specific impacts to the chub population.

In addition, research should be conducted to determine the relationship between flood events, or spikes in discharge, and successful spawning and recruitment. The influence of flood events may be related to: (1) timing of the spike; (2) duration of the spike; and/or (3) magnitude of the spike. Even though discharge below Bartlett and Stewart Mountain dams are regulated by SRP for hydroelectric power and irrigation, flood events are still realized and apparently have an effect on chub reproduction. Arizona Game and Fish Department needs to open dialog with SRP to explore scenarios that will allow for periodic spike flows to enhance roundtail chub reproduction and recruitment.

We also recommend the development and implementation of a roundtail chub recovery plan based on the following management needs: (1) watershed and stream flow protection; (2) research to determine the mechanisms of disappearance of the species; and (3) actions to

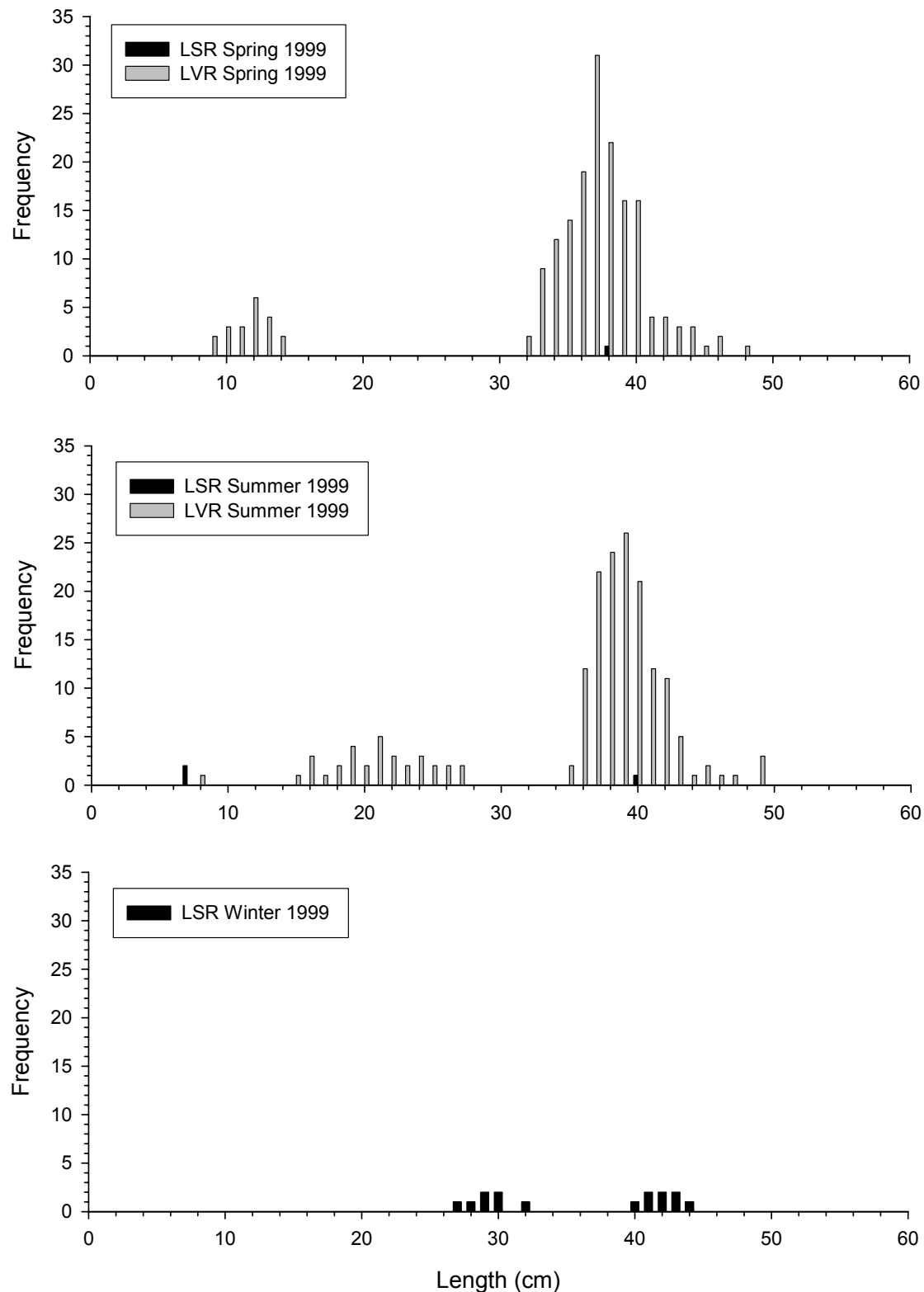
reduce the effects of nonnative fishes (AZGFD 1996). We further recommend the immediate development of a brood stock program to ensure the survival of at-risk populations such as the population in the lower Salt and Verde rivers. Finally, it is vital that we continue to monitor populations of roundtail chub to learn more about the mechanisms governing reproduction and survival.

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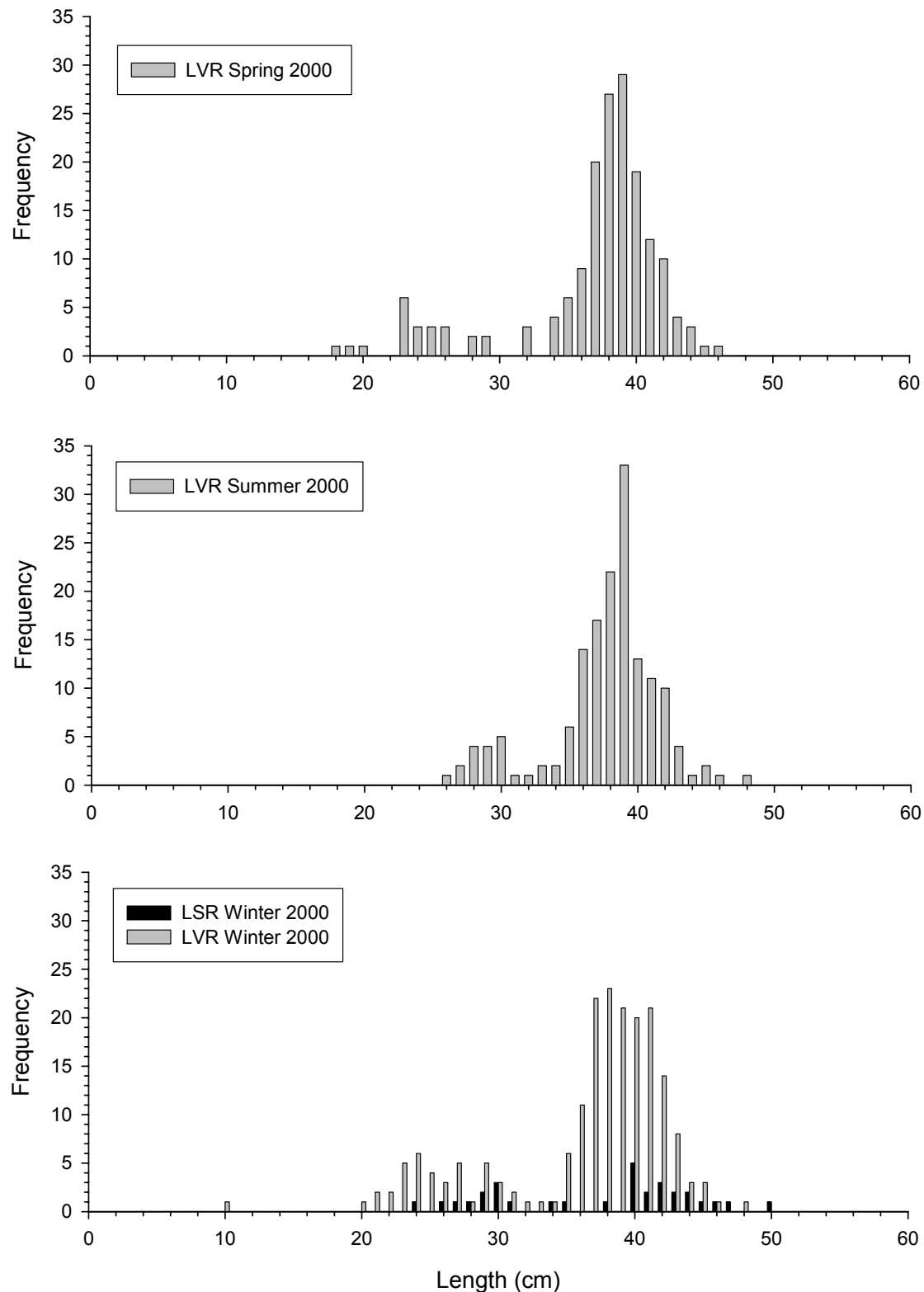
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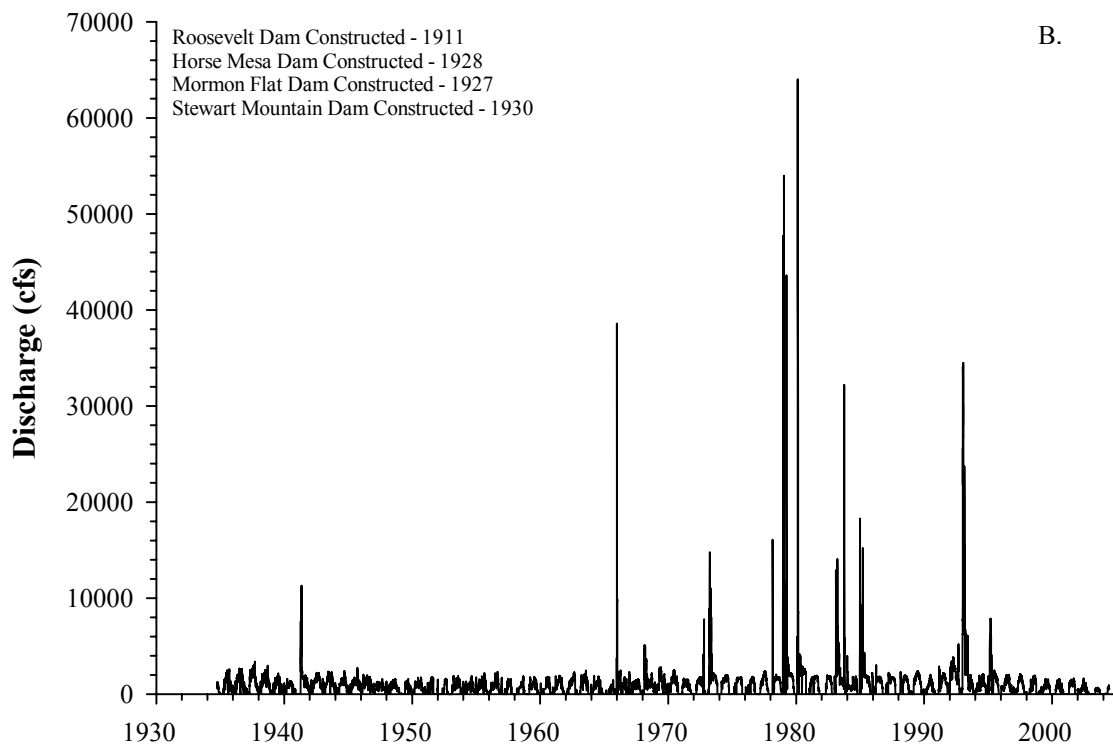
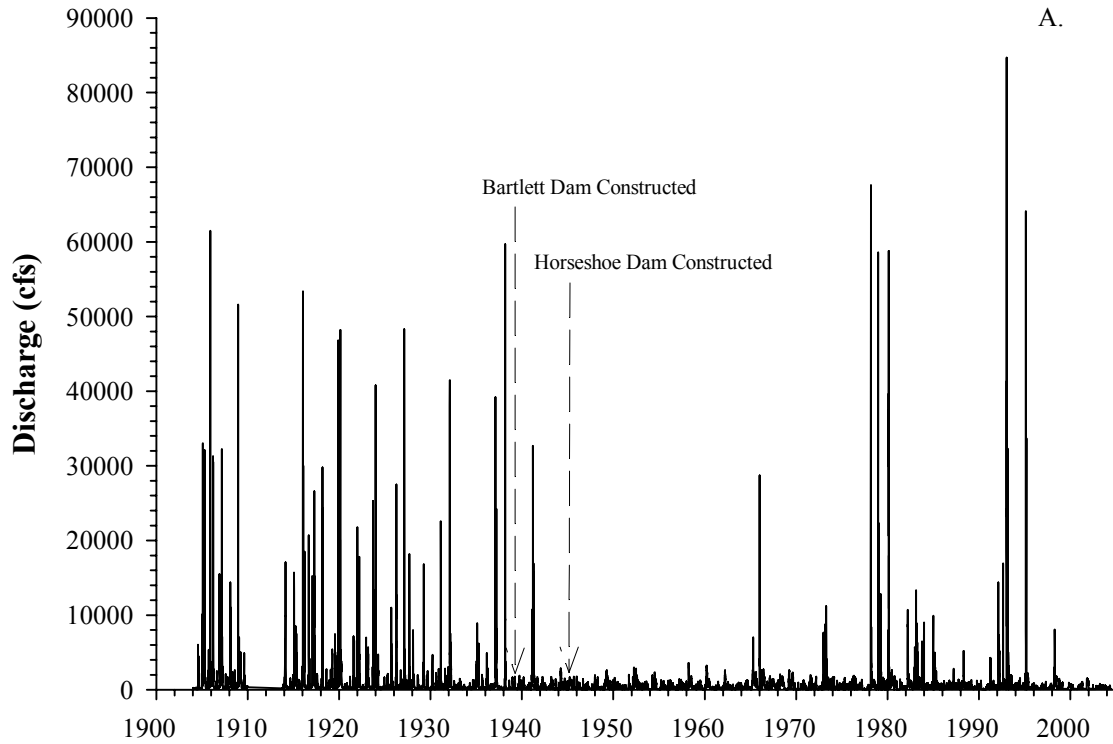
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APPENDIX A. - Length-frequency histogram of roundtail chub collected during the spring, summer, and winter, 1999 in the lower Salt and Verde rivers, Arizona.



APPENDIX B. - Length-frequency histogram of roundtail chub collected during the spring, summer, and winter, 2000 in the lower Salt and Verde rivers, Arizona.



APPENDIX C. - Discharge below the Bartlett Dam on the Verde River, Arizona, 1904-2004 (A) and below Stewart Mountain Dam on the Salt River, Arizona, 1934-2004 (B).